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New records of *Rhizocarpon* from Hengduan Mountains, China

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Abstract—Four species of lichen-forming fungi from Hengduan Mountains are reported new to Asia—*Rhizocarpon effiguratum*, *R. intersitum*, *R. subgeminatum*, and *R. umbilicatum*. These species are described and illustrated in detail and comments on their ecology and distribution ranges are provided.

Key words—*Rhizocarpaceae*, Asia, taxonomy

Introduction

The Hengduan Mountains is a large mountainous region in southwest China (22°–32°N 97°–103°E) and occupies parts of Sichuan, Xizang, and Yunnan Provinces. It consists of several mountain ranges, most of which run roughly north to south, and elevations span 4000–6000 m. Most mountain peaks are permanently covered with snow. Three great rivers of China, the Yangtze, Mekong, and Salween, run in deep parallel valleys separated by mountain ranges. Vast stretches of stones that serve as substrates for various lichens are common in this montane region (Fig. 1).

The Hengduan Mountains were chosen for study because of their rich lichen flora. There is a surprising lack of published information concerning the microlichens of this area. *Rhizocarpon* is a particularly under-studied genus, with only a few species previously recorded: *R. alpicola*, *R. geographicum*, *R. lavatum*, *R. rubescens*, and *R. sinense* (Wang et al. 2015, Zahlbruckner 1930, Zhao et al. 2013). Here we report four additional *Rhizocarpon* species

Fig. 1. The ecotope of Mt. Zheduo, located in Kangding Co., showing the typically rocky landscape in the Hengduan Mountains.

(*R. effiguratum*, *R. intersitum*, *R. subgeminatum*, *R. umbilicatum*) collected in the Hengduan Mountains as new to China as well as to Asia.

Materials & methods

Observations are based on material collected by the authors from Hengduan Mountains in 2015 and preserved in the herbarium of Shandong Normal University, Jinan, China (SDNU), and specimens held in the lichen herbarium of Kunming Institute of Botany, Chinese Academy of Sciences, Kunming, China (KUN-L). Morphological and anatomical characters were examined under an Olympus SZ stereomicroscope and an Olympus CX21 polarizing microscope. Both thallus and medulla were tested with K (10% aqueous solution of potassium hydroxide), C (saturated solution of aqueous sodium hypochlorite), I (10% aqueous solution of aqueous potassium iodide), and P (saturated solution of *p*-phenylenediamine in 95% ethyl alcohol) for identification. The lichen substances were identified using standardized thin layer chromatography techniques (TLC) with system C (Orange et al. 2010). Lichen photographs were taken with an Olympus DP72 camera attached to the Olympus SZX16 and BX61 microscopes.

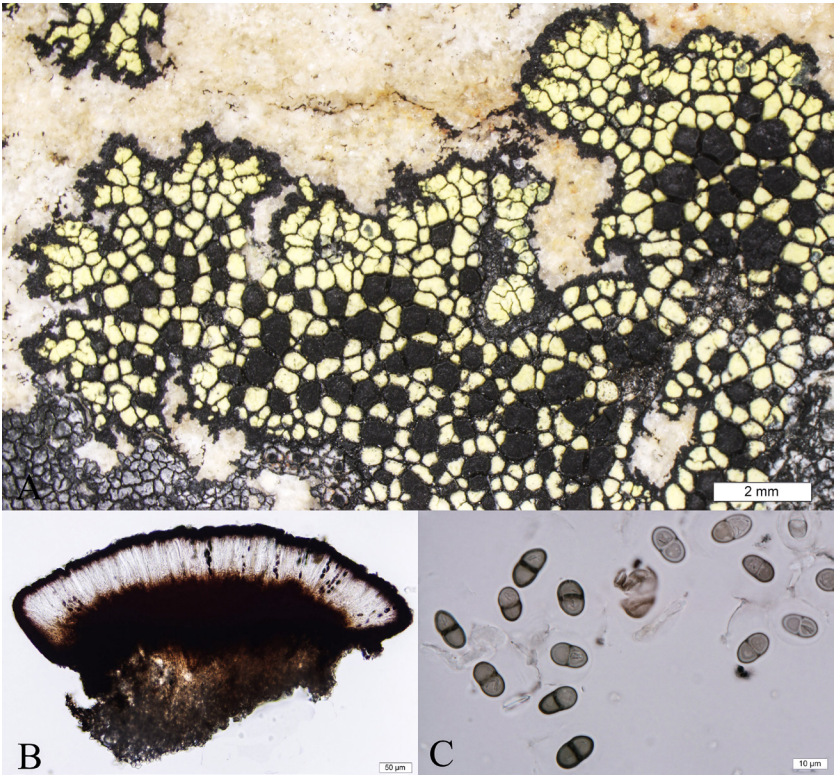

Fig. 2. *Rhizocarpon effiguratum* (SDNU Wang 20150590). A: habitus, distinct black prothallus along the margin of the thallus; B: apothecium section with brown-black epihymenium and poorly developed exciple; C: 1-septate, brown, halonate ascospores. Scale bars: A = 2 mm; B = 50 µm; C = 10 µm.

Taxonomic descriptions

Rhizocarpon effiguratum (Anzi) Th. Fr., Lich. Scand. 1(2): 613 (1874) Fig. 2

Saxicolous. Thallus bright yellow, areolate, ≤3.0 cm diam; medulla I+ violet; prothallus well developed, black, visible between the areolae and along the margin; areoles convex, matt, contiguous, round, 0.2–0.5(–0.8) mm diam. Apothecia 0.25–0.8 mm diam between the areolae, black, epruinose, angular, flat to convex, scabrid, margin persistent; exciple poorly developed; epihymenium green-black or brown-black, hymenium colorless. Asci 8-spored, *Rhizocarpon*-type; ascospores ellipsoid, 1-septate, dark green or brown, paler when young, halonate, 12–15 × 5–6 µm (n = 120).

Chemistry—Medulla K–, C–, P+ yellow; rhizocarpic and psoromic acids detected by TLC.

Specimens examined: **China**. **Xizang**, Chayu Co., Demula col, 29°19.15′N 97°01.75′E, 4794 m a.s.l., on siliceous rock, 23 Sep. 2014, Li S. Wang et al. 14-46628 (KUN-L); Zuogong Co., Xinde vil., 29°43.57′N 98°04.80′E, 4730 m a.s.l., on siliceous rock, 16 Sep. 2014, Li S. Wang et al. 14-45653, 14-45661 (KUN-L); Mt. Dongda, 5200 m a.s.l., on siliceous rock, 20 Aug. 2004, Li S. Wang 04-25614 (KUN-L); along the road from Mangkang to Zuogong, 4742 m a.s.l., on siliceous rock, 15 Sep. 2014, Li S. Wang et al. 14-45562, 14-45574 (KUN-L); Mangkang Co., Dogdala col, 29°05.48′N 98°36.94′E, 4930 m a.s.l., 17 Aug. 2007, Li S. Wang et al. 07-27990 (KUN-L). **Sichuan**: Ganzi City, Shiqu Co., Luoxv vil., Zebuka col, 4900 m a.s.l., on siliceous rock, 9 Sep. 2009, Li S. Wang 09-30462 (KUN-L); Litang Co., Mt. Haizishan, 29°41′32.79″N, 100°23′20.18″E, 4600 m a.s.l., on siliceous rock, 17 Oct. 2015, Wei C. Wang 20150591, 20150589, 20150593, 20150598, 20150599, 20150600 (SDNU); Litang Co., Mt. Tu'ershan, 29°31′00″N 100°16′11″E, 4896 m a.s.l., on siliceous rock, 17 Oct. 2015, Wei C. Wang 20150590, 20150592, 20150594, 20150595, 20150596, 20150597, 20150603, 20150604 (SDNU).

Distribution—*Rhizocarpon effiguratum* has been previously reported from Europe and North America (Anderson 1965, Timdal & Holtan-Hartwig 1988, Nimis 1993, Llimona & Hladun 2001). New to Asia.

Comments—*Rhizocarpon effiguratum* is a small lichen found in China on high mountains above 4000 m a.s.l. It is characterized by its yellow thallus with distinct black prothallus, I+ violet medulla, angular black apothecia, small brown 1-septate ascospores, and the presence of psoromic acid. *Rhizocarpon pusillum* Runemark and *R. parvum* Runemark are similar to *R. effiguratum* with small, pigmented, 1-septate ascospores, but both are lichenicolous and have a much smaller thallus (≤1 cm diam). *Rhizocarpon superficiale* (Schaer.) Malme, which also resembles *R. effiguratum,* is distinguished by its larger (≥6 cm diam) thallus, and different lichen substances: *R. superficiale* contains rhizocarpic, stictic, and hypostictic acids whereas *R. effiguratum* has rhizocarpic and psoromic acids. *Rhizocarpon alpicola* (Wahlenb.) Rabh. and *R. eupetraeoides* (Nyl.) Blomb. & Forssell have longer (≥18 µm) ascospores; Zahlbruckner (1930) reported the only known Chinese occurrence of *R. alpicola* from Yunnan Province. *Rhizocarpon norvegicum* Räsänen, another species similar to *R. effiguratum*, also produces brown 1-septate ascospores and an I+ violet medulla, but differs in its scattered thallus; it is known from Europe and North America (Thomson 1997).

Rhizocarpon intersitum Arnold, Verh. Zool.-Bot. Ges. Wien 27: 554 (1877) Fig. 3

Saxicolous. Thallus areolate, 2–3 cm diam; medulla I–; prothallus distinct, black; areoles dark grey, slightly to strongly convex. Apothecia black, epruinose, between the areoles, closely attached with areoles, up to 0.2–1.0 mm diam, flat to convex, margin present; exciple poorly developed, epihymenium

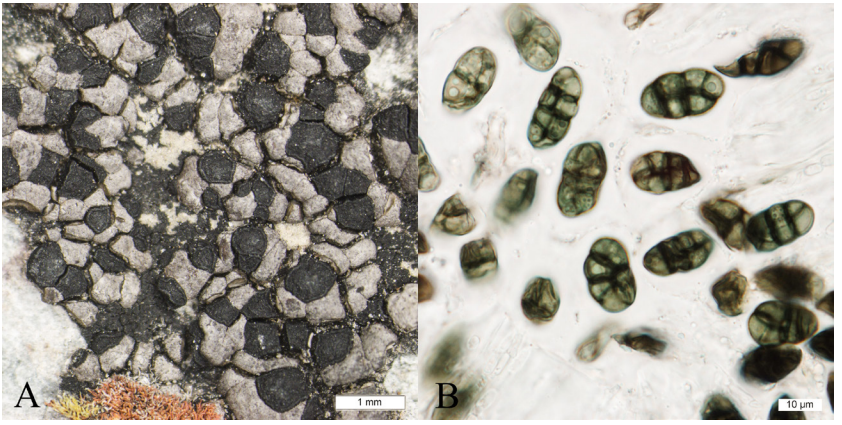

Fig. 3. *Rhizocarpon intersitum* (SDNU Wang 20150601). A: habitus; B: submuriform green halonate ascospores. Scale bars: A = 1 mm; B = 10 µm.

olive-green, K–; hymenium hyaline, upper part with green tinge, thick, ≥100 µm tall. Asci 8-spored; ascospores ellipsoid, submuriform, with 4–7 cells in optical view, dark green, halonate, 20–25 × 12 µm (n = 120).

Chemistry—Medulla K –, C –, P –. No lichen substances detected by TLC.

Specimens examined: **CHINA**. **Sichuan**, Xiangcheng Co., Mt. Daxueshan, 28°34′N 99°49′E, 4650 m a.s.l., on siliceous rock, 12 Sep. 2002, Li S. Wang 02-21488, 02-22354 (KUN-L); Luding Co., Mt. Gongga, Yajiagen, 29°54′36″N 102°00′14″E, 3800 m a.s.l., on siliceous rock, 13 Oct. 2015, Wei C. Wang 20150574 (SDNU). **Yunnan**, Jianchuan Co., Mt. Laojun, 26°38′12″N 99°47′08″E, 4000 m a.s.l., on siliceous rock, 25 Aug. 2015, Wei C. Wang 20150601 (SDNU).

Distribution—*Rhizocarpon intersitum* has been previously reported from North America and Scandinavia (Anderson 1965, Timdal & Holtan-Hartwig 1988). New to Asia.

Comments—*Rhizocarpon intersitum* is characterized by its dark 4–7-celled ascospores, an olive-green epihymenium, a distinct black prothallus, a dark grey thallus, and absence of lichen substances. *Rhizocarpon flavum* C.W. Dodge & G.E. Baker is close to *R. intersitum* but has a whitish or yellow to green-yellow thallus, a dark brown K+ purple epihymenium, and 2–6 ascospores per ascus.

Rhizocarpon subgeminatum Eitner, Jahresber. Schles. Ges. Vaterl. Cult. 88: 42 (1911) Fig. 4

Saxicolous. Thallus crustose, dark grey; medulla I–; prothallus black; areoles 0.2–0.7 mm diam, flat to slightly to convex, angular. Apothecia

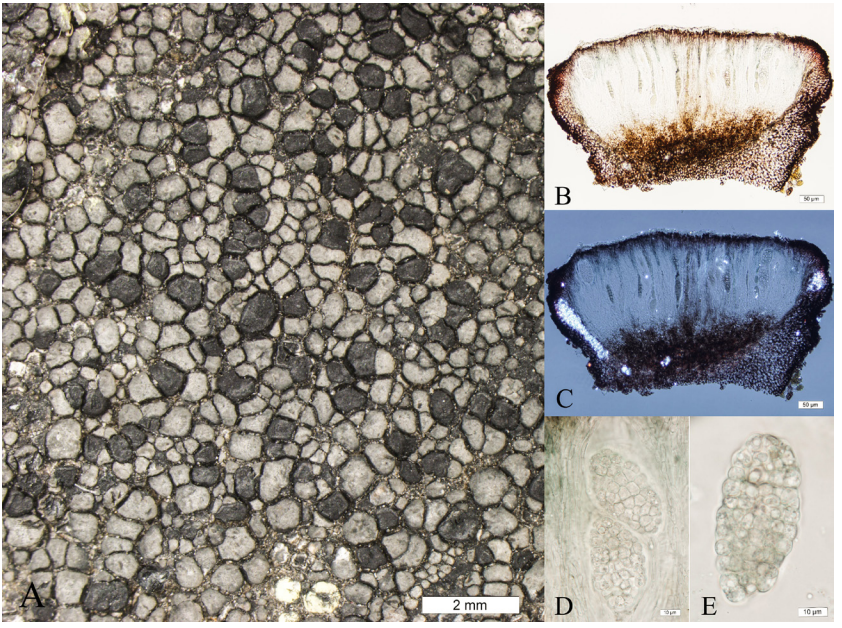

Fig. 4. *Rhizocarpon subgeminatum* (SDNU Wang 20150609). A: habitus; B: apothecium section; C: crystals in exciple (the sample was in water); D: two spores per ascus; E: muriform ascospores. Scale bars: A = 2 mm; B, C = 50 μm; D, E = 10 μm.

black, 0.5–0.8 mm diam, flat, between areoles, scabrid, epruinose; exciple well developed, black at the rim, inner part red-brown, containing crystals, extend to the bottom of hypothecium, ≤100 μm wide, K+ red; epihymenium red-brown, K+ red-purple (Atra-red); hymenium usually with pale green tinge, thick, about 125 μm tall. Asci 2-spored; ascospores ellipsoid, muriform, colorless, halonate, 37–55 × 20–25 μm (n = 30).

Chemistry—Medulla K–, C–, P–. Barbatic acid detected by TLC.

Specimens examined: **China**. **Sichuan**, Luding Co., Mt. Gongga, Yajiagen, 29°54′36″N 102°00′14″E, 3800 m a.s.l., on siliceous rock, 13 Oct. 2015, Wei C. Wang 20150605, 20150606, 20150607, 20150608 (SDNU); Kangding Co., Mt. Zheduo, 30°04′29″N 101°48′12″E, 4200 m a.s.l., on siliceous rock, 15 Oct. 2015, Wei C. Wang 20150609 (SDNU).

Distribution—*Rhizocarpon subgeminatum* has been previously reported from Europe and North America (Timdal & Holtan-Hartwig 1988, Fletcher et al. 2009). New to Asia.

Comments—Ihlen (2004), who reported a chemotype without lichen substances, suggested that one specimen containing barbatic acid was probably

contaminated by fragments of *R. rittokense*. However, the *R. subgeminatum* specimens collected in southwest China all contain barbatic acid detected by TLC, strongly supporting *R. subgeminatum* as having two chemotypes: 1) one with barbatic acid, and 2) one with no lichen substances.

Rhizocarpon umbilicatum (Ramond) Flagey, Mém. Soc. Ému. Doubs, sér. 6, 8: 98 (1894) Fig. 5

Saxicolous. Thallus rimose to areolate, white, pruinose, thick, 0.5–1.0 mm tall; medulla I–; prothallus present only along the margin. Apothecia black, immersed, epruinose, 0.5–1.5 mm diam, disc flat, margin distinct, usually with a white pruina. Exciple poorly developed; epihymenium green-brown K–, containing crystals; hymenium colorless, thin, about 120 µm tall, containing crystals. Asci 8-spored; ascospores ellipsoid, submuriform, with 6–10 cells in optical view, colorless, halonate, 25–30 × 15–18 µm (n = 30).

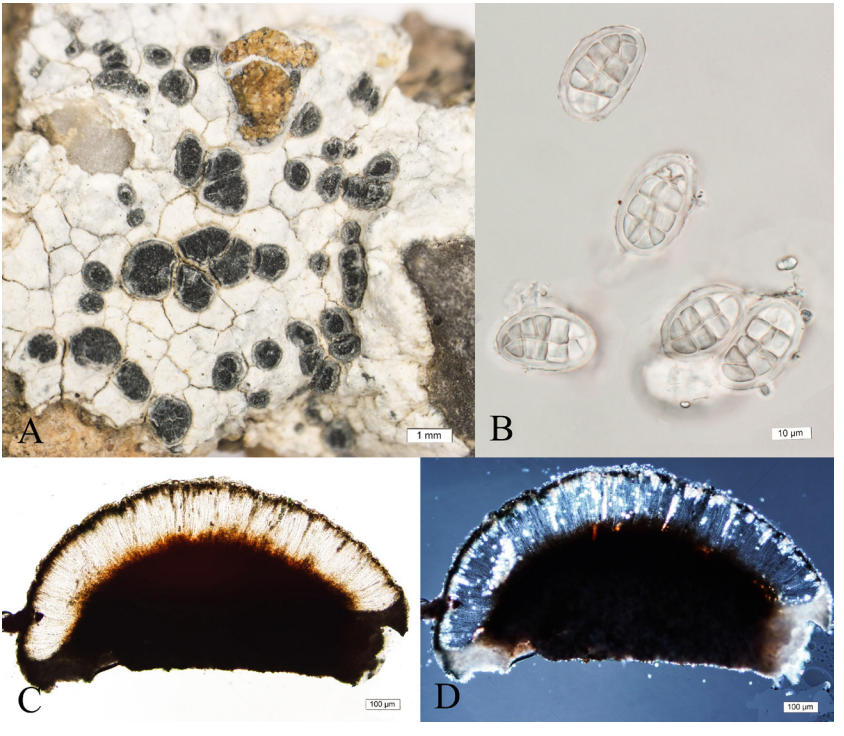

Fig. 5. *Rhizocarpon umbilicatum* (KUN-L Wang 94-15489). A: white thallus and apothecia with pruinose margin; B: submuriform halonate ascospores; C: apothecium section; D: crystals in epihymenium and hymenium (the sample was in water). Scale bars: A = 1 mm; B = 10 µm; C, D = 100 µm.

Chemistry—Medulla K+ yellow, C–, P+ orange. Stictic acid detected by TLC.

Specimens examined: **CHINA**. **Sichuan**, Yanyuan Co., Mt. Huolu, 4150 m a.s.l., on siliceous rock, 23 Jul. 1983, Li S. Wang 83-1199 (KUN-L); **Yunnan**, Deqin Co., Mt. Baimaxueshan, 4200 m a.s.l., on siliceous rock, 3 Oct. 1994, Li S. Wang 94-15489 (KUN-L).

Distribution—*Rhizocarpon umbilicatum* has been previously reported from Europe, North America, and Australia (Fletcher et al. 2009). New to Asia.

Comments—*Rhizocarpon umbilicatum* is close to *R. petraeum* (Wulfen) A. Massal., which differs by its longer (≥30 μm) ascospores and apothecia lacking a pruinose margin. *Rhizocarpon umbilicatum* is characterized by its white pruinose thallus, apothecia with pruinose margin, submuriform ascospores, and presence of stictic acid.

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